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Tests for Phosphate, Nitrate and Soluble Nitrogen in Conducting Tissue of Tomato and Lettuce Plants, as Indicators of Availability and Yield

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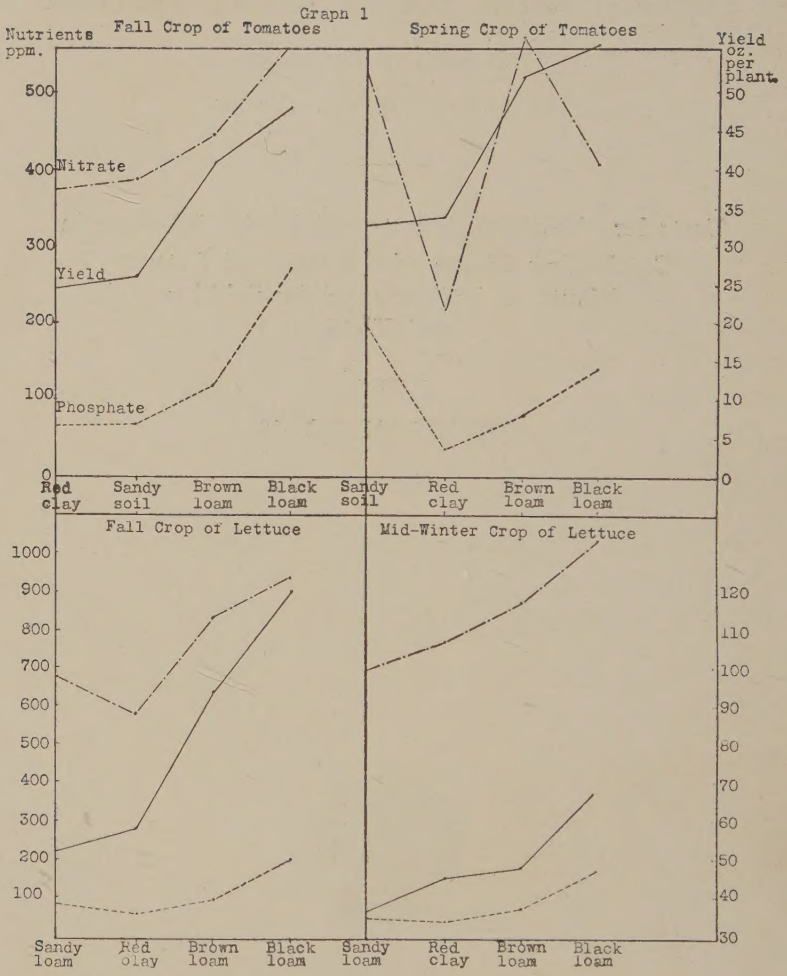

Nitrogen and phosphorus content, and yield, of tomato and lettuce plants on different soils.

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Tests for Phosphate, Nitrate and Soluble Nitrogen in Conducting Tissue of Tomato and Lettuce Plants, as Indicators of Availability and Yield

By E. M. EMMERT

If one could determine whether a given kind of plant is able to obtain the nutrients required for satisfactory growth on a given soil, there would be no guesswork about the use of fertilizers. The problem of determining the nutrients in the soil available to plants has received serious study but up to the present relatively little has been done to determine the relationship between the supply of nutrients in the plant and the availability of nutrients in the soil in which the plant is growing. In the study of nutrients in the tissues of the plant some workers have determined the total nutrients, while others determined the amount of nonsynthesized nutrients present. In this paper references to nutrients in the plant are to nutrients in solution in the conducting tissue, that have not yet entered into the process of metabolism.

Thornton (10) has summed up the literature on analysis for nutrients in the plant and has presented an adaptation of Bray's soil test for phosphorus (1) to plants, which he found gave excellent results with corn. Previous papers by the author (3, 4, 6, 7) present field and laboratory tests for soil nutrients in the conducting tissue of plants. The number of comparisons reported in these papers is small, but the degree of correlation with yield suggests the value of the tests in indicating availability of soil nutrients. The purpose in this paper is to present sufficient data to show that good correlation exists between the results of the tests and yield; hence that the tests indicate availability of nutrients to the plant. The work was done on tomatoes and lettuce in the greenhouse.

The general plan was to estimate the quantities of phosphate phorus and nitrate nitrogen or "soluble nitrogen" in the acid extract of conducting tissue taken from the lower part of a plant. Later the crop was gathered to determine the yield.

METHODS OF ANALYSIS

Plant Tissue. The analyses for nutrients in the plant were made in a similar way to the field tests previously described (6), but these procedures were modified for accurate work, as follows:

Method of Extraction. To make the extract, two to five grams of the enlarged part of the lower mature petioles of tomatoes or midribs of lettuce* were weighed as rapidly as possible, making as few cuts as possible before chopping up for grinding. The weighed sample was cut into about one-fourth to one-eighth inch sections and ground in a mortar with a few tenths of a gram of acid-washed charcoal (3). In the test for nitrate in tomato plants, 50cc. of 2 percent acetic acid was added gradually while grinding the mixture thoroly. In the test for soluble nitrogen in lettuce, only 10 cc. of 2 percent acetic acid was used. The solution was immediately filtered from the plant residue.

Notes. This method of extraction was used in order to obtain rapidity, give little chance for change, such as enzymic action, and obtain thoro extraction of the nutrients. Thornton (1) does not filter out the plant tissue. Filtering does not take long and is preferable. The author tried the Bray test without filtering, on tomato, lettuce and other tissues and found that while the blue color appeared, it was unstable, fading and turning greenish quickly, and that it was hard to make comparisons with a standard. Thornton states that the blue color rapidly fades and settles.

Some may object to the use of fresh tissue because of loss of moisture. Kraus and Kraybill (9) found this loss to be small and their results were not influenced appreciably. The author found that practically no moisture was lost where stem or petiole tissue was weighed immediately.

The reasons for using conducting tissue near the roots are: (a) Nutrients in this region are largely those coming directly from the soil. (b) The content of nutrients in this region is least affected by utilization in the regions of rapid growth. (c) The mature conducting tissue is more uniform in composition than tissue in regions of rapid growth, thus enabling the taking of comparable samples. Previous work (7) shows that even extreme drouth did not reduce the moisture content more than 1 or 2 per cent.

Nitrate Nitrogen. To 5 cc. of the plant extract, 1½ cc. of 10 percent NaOH solution was added, and the liquid evaporated to dryness in a 50 cc. Erlenmeyer flask. Two cc. of phenoldisulfonic acid was made to cover all the dry salts by rota-

*The lower main stem was not used except at the end of the experiment, when its use would not prevent estimation of total yields from the plants analyzed.

tion, 20 cc. of water was added after standing at least 5 minutes and 30 percent NaOH was added slowly until the yellow color reached its maximum intensity. The solution was made up to 50 cc. with water and compared in a colorimeter with a standard containing 0.0025 mg. of nitrogen as nitrate per cc.

Phosphorus. To 10 cc. of the tomato plant extract, 25 cc. of water was added, then 5cc. of 2.5 percent ammonium molybdate in 5 normal sulfuric acid, and 2 cc. of 1-2-4 aminonaphthol sulfonic acid reagent, prepared as directed by Fiske and Subbarow (8). The solution was made to 50 cc. and after 10 minutes compared with a standard solution containing 0.004 mg. P as phosphate per cc. Only 5 cc. of the lettuce extract was used, being made to 20 cc. The quantities of reagents were reduced in proportion.

Note. Stannous chloride has become common as a reducing agent in soil tests for phosphorus, while 1-2-4 aminonaphthol sulfonic acid is used quite often in biological work. Previous work (3) presents a number of points in favor of aminonaphthol sulfonic acid. The narrow range of acidity permissible with stannous chloride, and the variation in color seem to make that reagent undesirable for work with plant extracts. It is safer to use a reagent which is not so restricted in its acidity range. Furthermore, it is easy to compare different intensities of blue which remain blue even at great dilution. The greenish tinge that appears when stannous chloride is used probably depends on something else than phosphorus. The amount of tin present may be responsible for this off color, as the amount of stannous chloride present affects its intensity. The author found the aminonaphthol sulfonic acid reagent no more difficult to prepare and keep than stannous chloride. It seems just as easy to add a prepared reagent as to stir with a tin rod or add a small enough amount of a rather unstable salt.

Soluble Nitrogen. To 0.2 to 0.5 cc. of the lettuce extract (depending on age and size of sample) in an ordinary 25 cc. test tube, a granule of sodium chlorate about the size of a grain of wheat was added and 0.4 to 1.0 cc. of fuming sulfuric acid (15% SO_3) was run in from a pipette rather rapidly so that the solution boiled vigorously, causing complete oxidation, and decomposition of chloric acid. The chlorine was expelled by shaking and blowing across the top of the tube until a clear, colorless solution resulted. Immediately 0.2 to 0.5 cc. of phenoldisulfonic acid was added and mixed well. In 30 seconds to a minute, 5 cc. of water was added and 40 percent NaOH solution was run in from a pipette until the maximum yellow color developed. The solution was made to 20 cc. and compared with a standard in a colorimeter.

Soil. Total nitrogen and phosphorus in the soil were determined by methods previously described (2) (5) and pH by the quinhydrone electrode.

SOILS AND TREATMENT OF PLOTS

Soils. Four rather widely different soils were used, described as follows:

	pH	N*	P*
1. Black silt loam	6.2	3,125	9,400
2. Brown silt loam	5.8	2,551	4,208
3. Red clay	5.3	1,582	3,080
4. Brown silt loam mixed with an equal weight of sand	7.3	1,296	2,000

*Parts in 2,000,000.

Plant Beds. Raised benches, partitioned off every 4 feet were used. The cracks at the bases of the partitions were closed with cement to prevent exchange from plot to plot. Four tomato plants or 28 lettuce plants were set in each plot on the side benches (plots 1-8 and 31-38) which were 4 feet wide. Six tomato plants or 42 lettuce plants were set in each plot on the middle benches, which were 6 feet wide. Each tomato plant was pruned to one stem and given ordinary greenhouse care.

Treatments. The organic matter and alkali were mixed with the soil on September 6, 1932, for the fall crop, and the plots were watered heavily. The tomato plants were set the next day. The same treatments were repeated on March 15, 1933, and the tomato plants set March 18 for the spring crop. Sodium nitrate crystals and phosphoric acid solution were applied around the plants, one-third on September 19, one-third on October 17, and one-third on November 5, 1932. No nitrate was added to the spring crop, but 500 pounds per acre of superphosphate were added to the first three plots on each soil, at the time the plants were set. Lettuce followed tomatoes on the same plots, with only additional nitrate on certain plots as indicated in the tables. No more phosphate was added, but nitrate was added after the lettuce plants were set. The lettuce treatments were exactly the same for the first and second crops. Green soybean plants were used for green manure on the tomatoes, while green rye was used for lettuce.

RESULTS

EFFECT OF SOIL ON THE CONTENT OF PLANT NUTRIENTS AND ON YIELD

Graph 1, based on averages from Tables 1 and 2, shows the differences in content of nutrients maintained in the conducting tissues of tomatoes and lettuce grown on different soils. In the fall crop of tomatoes very good correlation exists between the yield and amount of nutrients present. Plants in the clay contained 66 ppm. of phosphate phosphorus and 375 ppm. of nitrate nitrogen, and produced 25 ozs. of fruit per plant whereas those in the black silt loam contained 272 ppm. of phosphate phosphorus and 582 ppm. of nitrate nitrogen, and yielded 48 ozs. per plant. Plants in other plots were intermediate in content of nutrients and gave intermediate yields. The correlation is not so good in the spring crop. If the sandy soil is omitted, however, the correlation is good with phosphate and fair with nitrate. These values for nutrients are not so representative as those for the fall crop because only two samplings were run on April 18 for eight plots, of each of the four soils, whereas findings for the fall crop are averages from 160 determinations from eight plots, run in duplicate at 10 different times thru the growing period. In the spring the sandy soil gave a low yield despite rather righ values for nutrients. This was because the sandy soil was located over the heating mains and dried out very rapidly. The plants were subjected to alternate dry and wet spells despite extra watering. The wet periods enabled good uptake of nutrients but the dry periods stopped normal utilization. This effect was not manifested in the fall crop because little heat was needed in the early stages of growth and cloudy weather prevented rapid drying out. This same effect is shown, but to a much less degree, in the lettuce crops. The weather was especially clear on the fall lettuce.

Otherwise, the correlation between yields of lettuce and nutrient supply is good and the differences between soils are similar to those observed with tomatoes.

THE EFFECT OF FERTILIZER ON THE CONTENT OF PLANT NUTRIENTS AND ON YIELD

From Tables 1 and 2, it is immediately evident that fertilizers almost always caused higher nutrient values in the plant. The effect of nitrate is especially apparent in the later stages of the growth of tomatoes, since in the mature plants on nitrated plots the nitrate remained almost as high as in the young plants, while the nitrate became very low towards the end in the plants on most of the plots that received no nitrate. The same is true for soluble nitrogen in lettuce, but the effect is not so pronounced. It is shown best in the winter crop. The December 6 results on the fall crop are high because the main stem was used for analysis, at the time of harvesting. The midribs undoubtedly would have run lower and the findings would have been more in line with the other results.

In practically all plots treated with superphosphate the content of phosphorus in the plant was raised in rough proportion to the amount of the treatment. The content of phosphorus was raised the most over the check in the low-phosphate soils, averaging from 2 to as high as 4 times the amount in the checks. This is not so much difference as with nitrate, since large applications of nitrate often caused over 20 times as much nitrate in tomatoes and 6 times as much soluble nitrogen in lettuce.

The yields accompanying addition of fertilizer are not so consistently raised as are the nutrients in the plant. This is to be expected since many factors may enter into the complex combination of factors which determines yield.

On the red clay, addition of both nitrogen and phosphorus, which increased both elements in the plant, caused a better increase in yield than either element alone. The tests for nutrients and the yield both showed that this soil lacked nitrogen and phosphorus in available forms. On the black silt loam addition of nitrogen lowered the yield. Addition of phosphate caused a slight increase. This soil was not significantly lacking in either element, which both nutrient tests and yields indicate.

Addition of phosphate to the brown silt loam produced the best increases in yields; phosphate and nitrate the next best;

and even nitrate alone caused substantial increases. Phosphorus seems to be limiting more than nitrogen, on this soil. The tests show that the plant starts out rather high in nitrogen but that nitrogen rapidly becomes limited. Phosphorus is less than half as much as in the plants on the black soil at all times. The sandy soil is seriously in need of both phosphorus and nitrogen as shown by the plant tests and yields.

EFFECT OF PHOSPHORUS AND NITROGEN ON EACH OTHER IN THE PLANT

Many figures in tables 1 and 2 indicate that an abundant supply of nitrogen causes rapid utilization of phosphorus and that the level of phosphorus in the plant becomes low if the soil is not capable of supplying it rapidly. If nitrogen is low, however, phosphate may accumulate and the level becomes abnormally high despite a low soil capacity to furnish phosphorus. This is shown in some of the limed soils. If phosphorus is especially high, as in the plots receiving a high addition of phosphorus (3 series), the nitrogen does not get so very low. In fact, it is often increased over the check. Presumably this is due to stimulated nitrification and liberation in the soil by available phosphorus. However, in soils with a low nitrogen reserve, as the red clay and sandy loam, there is a tendency towards lowering nitrogen below the check, because of rapid utilization of nitrogen in the presence of much phosphorus.

This utilization factor naturally will be noticed first and to the greatest extent in the new, rapidly growing regions. When one element is very limited for a considerable length of time, however, this effect is reflected even in the lower, older, conducting tissues. This effect in the older conducting tissues does not interfere with the interpretation of the test provided both N and P are tested for. This effect also helps to immediately make it obvious which element is limiting plant growth most. In plants with high nitrogen, phosphate may be zero in the growing points, but in the older conducting tissues the amount coming from the soil will still be detected. The same is true for the nitrogen coming from the soil if phosphate is high and nitrogen low. This utilization influence on plant tests may be overcome in practical field testing by making tests for both nitrogen and phosphorus and by using the concentration in normal high-yielding plants as a guide. For

TABLE 1. RESULT OF PLANT TESTS WITH TOMATOES

Soil	Treatment (Tons per acre)	Plot No.	Fall Crop Sept. 7 to Jan. 1932: Phosphate[1] Oct.	Phosphate[1] Nov.	Phosphate[1] Dec.	Nitrate[1] Oct.	Nitrate[1] Nov.	Nitrate[1] Dec.	Yield Oz. per plant	Spring Crop Mar. 18 to June 1933: Added treatment Tons per A.	Ave. in April PO_4	Ave. in April NO_3	Yield Oz. per plant	Av. pH for yr.	Plot
Red clay	0.5 N	1	43	28	5	877	771	667	29	0.25 P	17	300	39	5.43	1
	0.2 N, .35 P.	2	53	40	24	865	768	633	36	0.25 P	85	391	43	5.12	2
	0.2 N, .65 P	3	98	126	164	837	715	329	27	0.25 P	101	313	27	4.88	3
	Check	4	56	34	58	342	38	32	13	Check	25	50	23	5.24	4
	10 g. m.	5	53	55	54	740	176	27	33	10 g. m.	22	391	48	5.46	5
	4 c. s., 1 Ca.	6	51	87	149	68	39	24	14	4 c. s., 1 Ca	11	50	22	6.16	6
	4 c. s., 1 Ca, .25 Na	7	48	104	163	65	15	31	17	4 c. s., 1 Ca, .25 Na	22	50	28	6.37	7
	10 g. m., 1 Ca.	8	40	28	23	790	117	25	29	10 g. m., 1 Ca .25 Na	10	240	41	6.20	8
	Average		55	63	80	573	330	221	25		37	217	34		
Black silt loam	0.63 N, .3 P.	11	304	203	213	1,015	630	585	44	0.25 P	153	481	58	5.29	11
	0.7 N, .45 P.	12	293	296	208	945	949	778	45	0.25 P	200	447	43	5.46	12
	1.1 N, .6 P.	13	409	358	278	946	859	732	52	0.25 P	167	521	62	5.77	13
	Check	14	328	232	260	847	443	43	50	Check	167	348	62	6.09	14
	10 g. m.	15	380	293	206	841	623	22	52	10 g. m.	125	521	53	6.17	15
	4 c. s.	16	287	243	225	689	336	29	45	4 c. s., 1 Ca	91	100	63	6.45	16
	4 c. s., 1 Ca, .25 Na	17	359	236	218	864	145	20	50	4 c. s., 1 Ca, .25 Na	100	570	61	6.45	17
	10 g. m., 25 Ca, .25Na.	18	341	205	180	1,128	466	29	51	10 g. m., 1 Ca, .25 Na	111	223	66	6.51	18
	Average		336	256	224	909	556	280	48		139	401	59		
Brown silt loam	0.6 N	21	113	92	20	900	762	530	47	0.25 P	33	1,138	56	5.85	21
	0.4 N, .25 P	22	167	172	117	997	732	563	49	0.25 P	133	1,252	52	5.83	22
	0.2 N, .35 P.	23	235	204	228	823	677	153	62	0.25 P	153	962	66	5.82	23
	Check	24	141	119	156	756	137	25	34	Check	133	89	38	5.98	24
	10 g. m.	25	100	54	22	925	361	24	33	10 g. m.	59	417	59	6.10	25
	4 c. s., 1 Ca	26	95	112	148	508	11	22	32	4 c. s., 1 Ca	42	50	44	6.51	26
	4 c. s., 1 Ca, .25 Na	27	122	102	88	528	48	19	38	4 c. s., 1 Ca, .25 Na	59	38	43	6.78	27
	10 g. m., .5 Na.	28	100	76	56	725	442	57	32	10 g. m., 1 Ca. .25 Na	19	782	62	6.84	28
	Average		134	116	105	770	396	174	41		79	591	52		

Equal wts. of br. silt loam and sand	0.6 N	31	59	20	5	732	631	748	31	0.25 P	50	521	30	7.66	31
	0.6 N, .3 P	32	94	103	170	604	659	788	28	0.25 P	250	894	52	6.75	32
	0.4 N, .5 P	33	82	125	145	681	500	597	32	0.25 P	250	782	23	6.25	33
	Check	34	50	36	26	390	33	34	23	Check	286	41	23	7.42	34
	10 g. m.	35	58	48	12	860	151	22	23	10 g. m.	67	735	46	7.45	35
	4 c. s., .75 Ca, .25 Na	36	79	79	25	77	26	11	21	4 c. s., 1 Ca	250	47	25	7.64	36
	12.5 r. m.	37	151	99	46	575	120	16	27	4 c. s., 1 Ca, .25 Na	222	50	25	7.76	37
	10 g.m., .75 Ca, .25 Na	38	52	54	12	744	240	40	25	10 g. m., 1 Ca, .25 Na	200	1,138	41	7.70	38
	Average		78	71	55	583	295	282	26		197	526	33		

[1]Average of tests on 4 different dates in Oct.; 4 in Nov.; and 2 in Dec. Duplicate samples were run, making 20 determinations on each plot, on the fall crop.

g. m. = green manure. c. s. = cut straw. Ca = Ca (OH)$_2$. Na = Na_2CO_3. r. m. = rotted manure. N = $NaNO_3$. P = H_3PO_4.

TABLE 2. RESULTS OF PLANT TESTS WITH LETTUCE

Soil	Treatment in addition to the tomato treatments — Tons per acre	1st crop, Oct. 26 to Dec. 6, 1933[1]					2nd crop, Dec. 12, 1933 to Feb. 5, 1934[2]						
		Plot No.	Soluble N average		Phosphate average		Yield per plant—grams	Soluble N average		Phosphate average		Yield per plant—grams	pH	Plot No.
			Nov. 14, 25	Dec. 6	Nov. 14, 25	Dec. 6		Jan. 8, 15	Jan. 24, 31	Jan. 8, 15	Jan. 24, 31			
Red clay	0.2 N	1	492	735	21	54	49	1,123	667	17	13	34	5.7	1
	0.1 N	2	504	670	56	115	63	837	463	38	24	46	5.7	2
	High P	3	694	398	62	170	61	267	138	81	64	18	5.7	3
	Check	4	417	320	22	40	39	498	149	19	21	22	5.8	4
	10 g. m.	5	889	545	26	55	65	1,037	882	17	35	41	6.0	5
	4 c. s., 2 Ca	6	620	358	28	42	54	869	749	15	32	59	7.6	6
	4 c. s., 1 Na	7	576	350	49	58	66	1,087	1,309	27	74	85	7.6	7
	10 g. m., 1 Ca, .5 Na	8	985	658	27	42	68	1,019	1,179	24	47	55	7.8	8
	Average		647	504	36	72	58	842	692	30	39	45		
Black silt loam	0.2 N	11	815	1,250	109	456	111	1,342	823	196	136	60	6.2	11
	0.1 N	12	1,070	1,040	102	320	120	1,306	780	233	169	53	6.2	12
	High P	13	1,042	833	160	355	119	1,201	671	194	151	53	5.9	13
	Check	14	1,049	545	96	226	119	1,158	638	193	143	58	6.0	14
	10 g. m.	15	1,020	1,040	101	203	132	1,250	768	180	159	79	6.2	15
	4 c. s., 2 Ca	16	929	735	63	.....	109	1,232	765	157	97	68	7.3	16
	4 c. s., 1 Na	17	992	658	88	240	120	1,153	831	183	142	84	7.9	17
	10 g. m., 1 Ca, .5 Na	18	1,220	735	81	187	129	1,513	1,075	160	84	92	7.6	18
	Average		1,017	855	100	284	120	1,269	794	187	135	68		
Br. silt loam	0.2 N	21	892	1,040	38	124	81	1,225	927	76	32	42	6.2	21
	0.1 N	22	537	1,000	44	165	91	1,159	678	92	36	40	6.1	22
	High P	23	638	695	64	146	88	978	334	107	60	32	6.1	23
	Check	24	555	650	35	177	86	805	272	70	42	31	6.2	24
	10 g. m.	25	745	892	40	124	100	1,226	693	72	36	43	6.2	25
	4 c. s., 2 Ca	26	624	580	33	84	87	1,246	531	67	44	48	7.6	26
	4 c. s., 1 Na	27	540	1,060	41	205	107	1,452	1,032	124	120	80	8.1	27
	10 g. m., 1 Ca, .5 Na	28	750	2,082	50	114	115	1,473	964	104	105	63	8.0	28
	Average		660	999	43	142	94	1,070	679	89	59	47		

Equal wts. Br. silt loam and sand	0.2 N	31	405	1,135	21	80	38	1,115	838	44	30	25	7.5	31
	0.1 N	32	387	960	54	165	48	822	563	76	36	42	7.6	32
	High P	33	409	545	77	240	42	474	147	122	74	27	7.4	33
	Check	34	419	545	41	109	43	760	147	53	32	22	7.5	34
	10 g. m.	35	668	783	33	67	60	1,020	654	35	51	38	7.5	35
	4 c. s., 2 Ca	36	730	520	25	96	65	820	417	32	29	44	8.1	36
	4 c. s., 1 Na	37	750	800	28	150	48	1,020	510	28	39	47	8.1	37
	10 g. m., 1 Ca, .5 Na	38	832	1,785	25	100	68	1,136	751	31	24	40	8.0	38
	Average		475	884	38	126	52	896	503	53	38	36		

[1]Lower mature petitoles used on Nov. 14, and 25. On Dec. 6 the main large stem was used when they were harvested.
[2]Main stems of extra plants used on Jan. 8, 15 and 24. Petitoles on Jan. 31. The N treatments were repeated on the second crop.

instance, if tests for both nitrogen and phosphorus are made and the nitrogen is considerably less than in normal, high-yielding plants, but phosphorus is as much or more, it is safe to conclude that nitrogen is needed, but not that phosphorus is plentiful. If, after adding nitrogen, the nitrogen gets normal and the phosphorus stays normal then no further treatment is necessary. But if the soil is not supplying sufficient phosphorus, as soon as nitrogen is plentiful the phosphorus test will become low and indicate the need of available phosphorus. The phosphorus and nitrogen concentration in a given section of the more mature conducting tissues at a certain stage of growth of a high-yielding plant will be fairly constant, as indicated by the results on the black silt loam soil presented in the tables, and may be used as an indicator of the amounts which should be present.

SOME ADVANTAGES OF TESTS FOR NUTRIENTS IN THE PLANT

1. Nutrients in solution in the conducting tissues of a plant are actually available to the plant.

2. The presence of interfering substances is not to be feared, because the gross composition of a given plant is fairly constant, regardless of the soil in which it grows.

3. Particular demands of each crop are considered in the plant tests. The optimum level of nutrients for the various stages of growth for each crop may be determined and soil treatment regulated to obtain this optimum as nearly as possible.

4. Plant tests enable the rapid determination of whether a particular soil treatment is actually overcoming nutrient deficiencies.

5. The plant tests show whether a soil is supplying too much of a certain nutrient in relation to the other nutrients which are being supplied.

6. The concentration of nutrients in the plant extract is sufficient to permit rapid and accurate tests on small quantities.

7. Differences in the nitrogen and phosphorus content in the conducting tissues, corresponding with differences in the soil, are quite large, which makes it easy to draw definite con-

clusions from the tests. The differences are much larger than differences in the total content of these elements in the plant.

8. If these tests enable one to follow the nutrient levels in the plant from early to later stages of growth they will make it possible for one to supply fertilizers and soil treatments as they are needed.

SUMMARY

Tomatoes and lettuce were grown on four widely different kinds of soil and various fertilizer, alkali and organic matter treatments were given to each soil. The lower petioles of tomatoes were analyzed for nitrate nitrogen and phosphate phosphorus. The midribs of lettuce were analyzed for phosphate phosphorus and soluble nitrogen. Records of yields were compared with the results of the analyses to determine whether these plant tests indicated availability of nutrients to the plant and whether amounts of the nutrients in the lower conducting tissues were proportional to the yield. The data presented indicate the following points:

1. That the content of nitrogen and phosphorus in the conducting tissue of plants growing in the different soils correspond well with the productiveness of the soils as measured by the yield.

2. That the effect of fertilizers is readily detected by the tests on the plants.

3. That the amount of nutrients in the conducting tissue of a plant seems to be definitely related to yield.

4. The largest yield of tomatoes occurred on the plots treated with superphosphate and on plants showing the largest phosphate in the conducting tissues.

5. The amount of phosphate in the conducting tissue was influenced by the amount of nitrate or soluble nitrogen present. A large amount of nitrogen decreased the phosphate content, while a small amount was accompanied by increase of phosphate. This indicates the importance of testing for both elements in order to determine which one is limiting.

6. This interrelationship between nitrogen and phosphorus probably is caused by utilization of nitrogen and phosphorus by the plant. The presence of abundant nitrogen as compared with phosphate causes a heavy utilization of phosphorus and a decrease in the phosphate content of the conducting tissue. If the supply of phosphorus is inadequate, the quantity in the conducting tissue becomes very small, but if the supply is sufficient, the amount in the tissue is moderate. On the other hand, if nitrogen is deficient, phosphate may accumulate.

7. Some advantages of rapid tests for nutrients in the plants are presented.

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